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A PRELIMINARY REVIEW OF THE POTENTIAL AREA TO DEPLOY WAVE ENERGY CONVERTER IN KUALA TERENGGANU SHORELINE

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ABSTRACT

Malaysia has a total landmass of 330,800 square kilometers with shoreline totals approximately 4,800 km. Separated by the South China Sea into two regions, Peninsular Malaysia and East Malaysia. Due to the long shoreline, wave energy potentially provided free source of green energy and still huge possible to discover. Ocean wave is huge, largely untapped energy resource, and the potential for extracting energy from waves is considerable. There are various types of wave energy converters available in the market. Wave energy converters are used according to the specific needs, location and magnitude of a particular project. Wave energy is a green source that can be enhanced with the help of latest technological advances. This preliminary study will lead to finding some very interesting facts about wave energy which can be reviewed and further analyzed. The findings led to a proposal of wave energy converter development in Kuala Terengganu.

Keywords: *Wave Energy Converter, Malaysia Coastal Water, Green Energy, Ocean Wave*

1.0 INTRODUCTION

Ocean energy comprise of 3 important elements i.e. wind, waves and currents that can create an energy conversion technology that can be classified based on specific needs, location and magnitude usage for power generation [1]. Several studies on this subject already been conducted worldwide to prove the concept of wave energy. In year 2000, oscillating water column type was installed at Islay, Scotland shoreline for producing power to National Grid [2]. The most famous study is the Pelamis power generating devices built by Pelamis Wave which operates in Northern Portugal in 2008 [3, 4]. Recent study conducted by British engineering consultant, Baird & Associates reported Chile is the country with the highest wave energy potential in the world [5]. Officially, wave energy along Chile's coast can cover up to 24 percent of the country's energy demand in summer and 26 percent in winter [6, 7].

Long coastal line in the east cost of Malaysia providing an initial need to use the ocean wave energy. This paper discusses the possibility of using ocean waves in Kuala Terengganu shoreline. The reviewed literature includes the available technology that can be used to convert the current wave energy into electricity by using existing and new technology in the market.

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The first element is the wave. Different criteria of wave's shows specific characteristics to distinguish wave types. The orientation of the particle movement relative to the direction of the dispersion of energy is one way the wave is categorized. The wave categories are Longitudinal Wave, Transverse Wave, Surface Wave and Raleigh Wave [7].

Second element is the current that acted as support to the energy devices. There are 2 types of currents; surface currents and deep-water currents [8]. Wave energy converters generally have 8 different types of devices i.e. Attenuator, Point Absorber, Oscillating Wave Surge Converter, Oscillating Water Column, Overtopping, Submerge Pressure Differential, Bulge Wave, and Rotating Mass [9]. WEC consists of mechanism and structure of equipment to assist for energy conversion power supply to every sector requirement [10]. There are four classifications of WEC that are commonly used today that are classified according to Operation Principal, Location, Power Take-Off System, and Directional Characteristics [11]**.**

2.0 TYPES OF WAVE ENERGY CONVERTER

Historically, the converter patent was invented since 1799 in Paris by Girard's family. The era for the devices research and development has been constructed since 1910 by Bochaux –Praceique with his first oscillating water-column type of wave-energy device. The introduction of the modern technology of wave energy has been inspired by Yoshio Masuda's experiments in the 1940s. The concept of power extraction from angular motion at the articular raft joints has been proposed in the 1950s by Yoshio Masuda's [12]. Summary of the devices converter is described in Table 1.

Table 1: Summary of converter devices data record [9, 13]

Converter	Operating Principal	Devices	Character
Attenuator	A segment of separate attenuating linked with the hydraulic cylinder double acting type to generate the power under lower forces condition parallel to the wave motion.	- Dexawave - Pelamis	Accumulator
Point Absorber	Derived from the relative buoy movement which is connected to a several sub surface components during any wave motion. The energy converted by electromechanical or hydraulic mechanism to generate power	- Power Buoy - Lopf - SeaRay - Seatricity - Wave Star - Bolt Lifesaver - Wet-Nz - Seabased	Accumulator
Oscillating Wave Surge Converter	Contains float or paddle which mounted to the seabed for reaction to surge of wave motion linked to the onshore hydro power turbine.	- Oyster - Bio Wave - Wave Roller - Langlee - Surge WEC	Accumulator Reservoir
Oscillating Water Column	Direct acting from wave reaction which forced through the turbine passage by compressed air column.	- GreenWave - BlueWave - Og Wave - Limpet	Flywheel

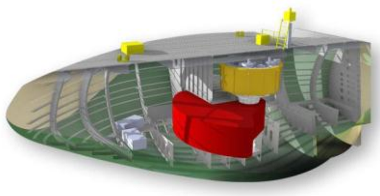
Converter	Operating Principal	Devices	Character
	Air inside the turbine will draw back when percentage wave reduces.	- OE buoy - Drakoo - Pico	
Overtopping	The quantities of waves are passing thorough ramp and impounded into the reservoir then returned to the sea through an axial turbine blades and generates the electricity.	- Wave Dragon - Wave Plane	Reservoir
Submerge Pressure Differential	Operates with a different pressure reaction will force air inside the membrane compressed in the Archimedes Wave Swing device.	- CETO - Archimedes Wave Swing	Accumulator
Bulge Wave	Depends on the geometry and properties of the tube material to create the wave velocity passing through and squeezing the water inside the tube and at certain period it will expand the material by collecting wave energy.	- Anaconda	Elastic Walls
Rotating Mass	Driven by mechanical energy for converting ocean energy to produce the mechanical rotational within buoys and creates power through an electrical generator built in.	- Wello Penguin	Gyroscope

3.0 RECENT DEVELOPMENT OF WAVE ENERGY CONVERTER

The target of development achievement by any regulatory agency involved R&D wave energy contributed to the improvement of concept and design of the energy devices.

Recently Wello Oy's Penguin devices arrived at Orkney in early February 2017 and was deployed on March 2017 at the European Marine Energy Centre (EMEC) site. The implementation at the first stage in the construction an array of three Wello Oy's devices at Billia Croo grid. The device was designed to be durable even during harsh ocean condition and can swell up to 18 meters at EMEC site in Orkney, Scotland [14]. The next development site is Nusa Penida Island in Bali which is expected to be launched by end of 2018 [15]. This converter devices proportional to buoyancy outer hull shape and it has a characteristic feature that can follow wave formed subsequently encased in asymmetrical body in rotational mechanics to mass in linear mechanics reflect by wave motion. It is depending on mass and distribution of that mass relative to the axis of rotation. The working principal of these wave converters driven by mechanical energy for converting ocean energy to the mechanical rotational/kinetic energy within buoys and creates power through an electrical generator [16]. The movement of mechanical rotational is linked to an electric generator equipped inside the device. The momentum gradually changing depends on mass motion inside vessel around the circle. This motion spans either eccentric weight or gyroscope causing precession and is held in place by three wires anchored to seabed. It is representing a great value with low maintenance and operation cost. Overall it has a longer lifecycle than an average wind power plant [17, 18].

In Japan, the technology has been adapted to the hybrid system called SKWID (Savonius Keel&Wind Turbine Darrieus). It was installed 1.2 km off the coast of western Japan, Kabe Island on December 2014 by MODEC's. The system is capable to generate power from wave, currents and ocean winds. Figure 1 shows recent development of Wello Penguin and SKWID WEC [19].



Wello Penguin

SKWID

Figure 1: Recent development wave energy converter

4.0 POTENTIAL DEPLOYMENT AREA OF WEC IN KUALA TERENGGANU

Four spot areas have been proposed for WEC deployment as shown in Table 2. First station from location of mooring AWAC deployed proposed at coordinate 103.26555556°E 5.44285000°N [20], second station at 103.04194444°E 5.77513333°N, third station at 102.93333333°E 5.58333333°N and fourth station at 103.00472222°E 5.82107500°N. For the 2nd and 4th station is based on study by A. Mirzaei, F. Tangang, and L. Juneng, "Wave energy potential along the east coast of Peninsular Malaysia," [21] and 3rd station is based on study by Loon and Koto [22]. Table 3 shows 5 yearly mean significant wave height (H_s) and wave period (T_M). It is observed that wave height is higher in 2011 then followed by 2009, 2008, 2012, and lastly 2010. Average for all stations from 1-4 are on the same grid, depth, the exposure and distribution of the wave climate are also the same for each year in particular [23].

Table 2: Potential location to deploy WEC in Kuala Terengganu shoreline [21]

Descriptions	Station 1	Station 2	Station 3	Station 4
Source	[20],[23]	[21],[23]	[20],[22],[23],[24]	[21],[23]
Location	~17km from Sultan Mahmud Airport, Kuala Terengganu	~1km from Redang Holiday Beach Villa, Redang	~ 5 km from Merang Jetty	~1km from Chagar Hutang Turtle Sanctuary, Redang
Coordinates	Lon: 103.26555556°E Lat: 5.44285000°N	Lon: 103.04194444°E Lat: 5.77513333°N	Lon: 102.93333333°E Lat: 5.58333333°N	Lon: 103.00472222°E Lat: 5.82107500°N
Depth	19m	14m	20m	>20m
Significant Wave Height	0.1 – 3.5m	1-3m (annual mean)	0.1-3.1 m	1-3m (annual mean)
Wave Energy Flux	<5kW/m	<5kW/m	<4kW/m	<5kW/m

Table 3: Annually Wave height record [23]

Wave Height/Period	Year 2008	Year 2009	Year 2010	Year 2011	Year 2012
H_S	0.7m-1.03m	0.71m-1.06m	0.61m-0.87m	0.65m-1.10m	0.64m-1.10m
T_M	6.0s-6.63s	6.03s-6.23s	5.68s-5.93s	6.2s-6.5s	5.87s-6.05s

4.1 Existing WEC Research & Development in Malaysia

Recently WEC in Malaysia is being under R&D with a numerous experiment at some of the universities lab and institutes. Existing R&D in wave energy converter is PV-Wave hybrid system controlled by environmental condition to achieve the power output. The PV system is equipped with integrated system and battery bank. The designed concept used to drive a bidirectional air turbine during sea motion heave up or down in the chamber which convert the kinetic energy into mechanical energy for electrical power. The major main parts in the hybrid system are PV system, OWC System, Battery Bank, a BBDC (buck-boost D.C) with proportional integral (PI) control duty cycle**,** and a pulse width modulation (PWM) insulated-gate bipolar transistor (IGBT) VSI located at the load side. The wave hybrid system is the beginning project of the standalone prototype hybrid photovoltaic- (PV-) correlated with energy storage usage. PV model is used to generate power from solar radiation and the results simulation test maintains dc power at constant value with difference power and load power requirement in hybrid generator. Figure 2 shows block diagram of a wave energy converter hybrid system [25].

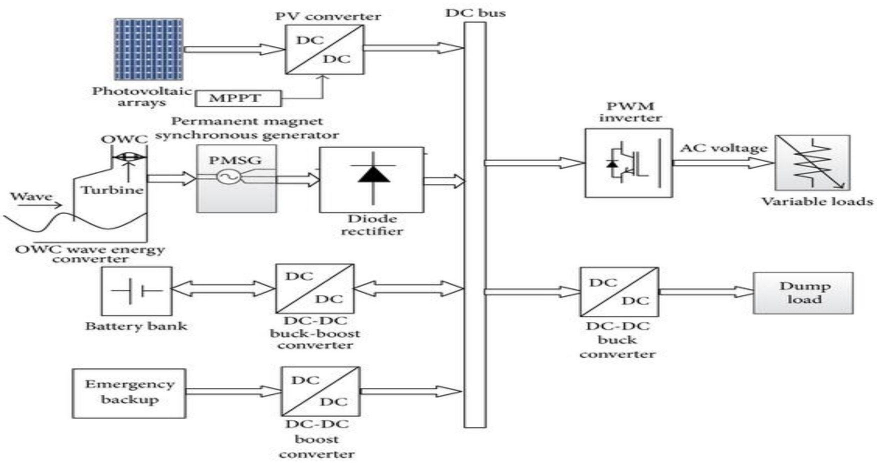


Figure 2: Block diagram of the standalone PV-wave hybrid system [25]

4.2 Proposed Location of WEC's Deployment

The designed WEC requires details specification in terms of sea state characteristics. To select the potential location for the WEC to be allocated, it is mandatory to provide a detailed description of the wave climate conditions as well as the estimates of available power. Hence, the analysis to evaluate and forecast Kuala Terengganu coastal wave sources at several locations in catering all the weather conditions information.

The investigation over a period for wave potential from the database has been recorded and collected with regards to wave height and period thorough several articles. Deployment devices at South China Sea coastline as listed in Figure 3 have been proposed with the aim to identify the most potential locations for a project of wave energy converter. Table 4 shows the metric data for the devices of target value. The power grid requirement to deploy WEC devices minimum 6 units with each unit can produce output power around 5 watts. The location for grid to be establish around 10 meters or more with average wave height 0.4 meters annually.

Figure 3: Station 1 - 17km from Sultan Mahmud Airport, Kuala Terengganu (Lon: 103.26555556°E Lat: 5.44285000°N) [20]

Table 4: Target Metric Converter Proposed

Metric No.	Devices Metric	Units	Limitation
1	Power Output	Watts	> 5
2	Working Period	Months	> 6
3	Number of Converter	Units	< 6
4	Max. Wave Height	Meters	> 0.4
5	Depth Area to Deploy	Meters	> 10

5.0 CONCLUSIONS

An assessment of Kuala Terengganu shoreline wave energy resource has been conducted throughout the analysis of data records for sea state and wave energy converter characteristics. Both characteristics have been evaluated, and it was found that the energy rich areas are concentrated in Kuala Terengganu with a range of average year wave energy was 17.69 MWh/m and the average wave power between 0.15 to 6.49kW/m [20]. Generally, a main direction in terms of wave energy demonstrates that the strong variability of wave height exists during North-East season which 80% of total wave energy [24]. The conclusion from this paper is that the possibility to utilize wave energy in Peninsular Malaysia with the case study in Kuala Terengganu shoreline now has a significant wave energy source that can be exploited to strengthen demand for energy use. This will help to demonstrate the ideal location for wave power exploitation. Analysis data showed the capability of local flow behavior predictions that can be used in a WEC selection.

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